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Usefulness of the multiplanar reformatting mode of three-dimensional echocardiography in evaluating valvular and structural heart disease: An experience from Saudi Arabia

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Objective: **The aim of this study is to compare the feasibility and capacity of multiplanar reformatting (MPR) mode of three-dimensional echocardiography (3DE-MPR technique) with two-dimensional echocardiography (2DE) for visualizing morphological details during evaluation of congenital heart disease (CHD). The study also seeks to validate the accuracy of 3DE MPR in determining cardiac valvular lesions and the application of the 3DE-MPR technique in daily clinical practice.**

Methods: **A cross-sectional study was carried out at Madinah Cardiac Centre, Saudi Arabia from May to December 2012. Various forms of CHD were diagnosed in 43 patients by conventional 2DE, and the patients were then examined with the 3DE-MPR technique using dedicated software and a standard protocol.**

Results: **Of the 43 patients, 23 (53.5%) were males and 20 (46.5%) females. Their age varied from 30 days to 146 months (mean age, 70.2 months and SD = 42.5 months) and their weight from 4 to 42 kg (mean weight, 20.2 kg and SD = 9.7 kg). The 2DE showed left heart lesions in nine patients (20.9%), right heart lesions in 23 (53.5%), atrial septal defects in five (11.6%) and complex CHD in six patients (14%). The 3DE MPR technique application and analysis was possible in all patients. The study demonstrated the fields where 3DE MPR was of additive value to conventional 2DE for the vena contracta area in valvular regurgitation severity and the planimetry for the valvular stenosis precise estimation, enface views of atrial septal defects with direct visualisation of shape and size of the defect, and segmental analysis of complex CHD using one window. The clinician and surgeon were then able to determine the mechanism and severity of the lesions and thus decide on appropriate treatment and management.**

Conclusion: **The study demonstrated the usefulness of 3DE-MPR as a complement to conventional 2DE. The technique is a significant technological breakthrough that allows instant visualization of morphological details and precise determination of cardiac valvular lesions, which were less clearly delineated by 2DE alone.**

Keywords: Congenital heart disease, Echocardiography, Three-dimensional echocardiography, Two-dimensional echocardiography, Multiplanar reformatting

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Introduction

Conventional 2DE is the most common diagnostic modality used by clinicians in echocardiography laboratories to evaluate congenital heart disease (CHD). In 1974, Dekker et al. [1] at Stanford University, California (USA), obtained the first three-dimensional (3D) ultrasonic images of the human heart. In the early 1990s, Von Ramm et al. [2] at Duke University in North Carolina (USA) developed primitive versions of real-time three-dimensional echocardiography (RTT-3DE), but the long post-processing time for offline reconstruction and suboptimal image quality limited its widespread clinical use [3]. In the past three decades, further advances have been made, and several generations of echocardiographic machines with advanced computer technology have been developed [4]. The real breakthrough in 3DE technology came in 2002, when fully sampled matrix-array transducers became commercially available. Since then, further advances have been made in 3DE computer software technology, with the development of an advanced matrix transducer capable of acquiring 2DE and 3DE views with a single transducer in the same setting. This development has led to better evaluation of valvular and CHD in both paediatric and the adult populations [5].

Abbreviations

MPR	multiplanar reformatting
3DE-MPR technique	three-dimensional echocardiography multiplanar reformatting technique
CHD	congenital heart disease
2DE	two-dimensional echocardiography
3DE	three-dimensional echocardiography
RTT-3DE	real-time transthoracic three-dimensional echocardiography
DICOM	digital imaging and communications in medicine
RA	right atrium
RV	right ventricle
2D-TTE	Two-dimensional transthoracic echocardiography
SD	Standard deviation
TR	tricuspid regurgitation
VCA	vena contracta area
TV	tricuspid valve
VC	vena contracta
TVS	Tricuspid valve stenosis
TVP	TV prolapse
DORV	double outlet right ventricle
VSD	ventricular septal defect
TOF	Tetralogy of Fallot
LPA	disconnected left pulmonary artery
MR	Mitral regurgitation
MV	mitral valve
MVS	mitral valve stenosis
MVA	mitral valve area
MVP	mitral valve prolapses
PSLAX	parasternal long axis
LA	left atrium
AR	aortic valve regurgitation
VCW	vena contracta width
AVS	aortic valve stenosis
AoV	aortic valve
AS	Aortic stenosis
AVA	aortic valve area
LVOT	left ventricular outflow tract
LV	left ventricle
ASD	atrial septal defect
CW	continuous wave Doppler
TEE	transesophageal echocardiography
ECG	Electocardiogram

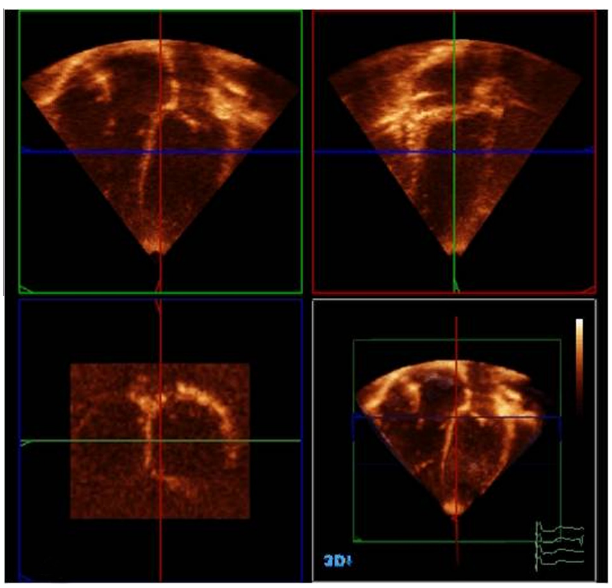

Figure 1. The acquired RTT-3DE datasets were stored on the machine's hard disk in the DICOM format. The datasets were analysed off-line with QLAB Advanced Quantification software (Philips Ultrasound, USA) installed in the IE-33 echocardiography machine (Philips, Bothell, Washington, USA). The MPR button is activated, and the echograph displays three colour-coded imaging planes (similar to 2DE planes) that move spontaneously. Any cardiac structure of interest to the operator (e.g. atrioventricular valves, intratrial or interventricular septa) can be evaluated individually by moving the colour-coded bar, and the structure of interest can be evaluated in the corresponding colour-coded box. The fourth plane showed a full 3DE image (in the lower right quadrant).

The acquired RT-3DE datasets are stored in the digital imaging and communications in medicine (DICOM) format on the machine's hard disk with Q-lab software (Philips Ultrasound, USA), which is installed in the machine. The data can be analysed by direct cropping and MPR techniques. In direct cropping, the desired planes are obtained by applying direct slicing to full-volume datasets; for example, the upper half of the right atrium (RA) and the lower half of the right ventricle (RV) starting from the RV apex are removed to obtain an enface view of

Table 1. New findings provided by three-dimensional echocardiography dataset analysis with the multiplanar reformatting mode technique (3DE-MPR) as compared with two-dimensional echocardiography (2DE).

No.	Diagnosis	No. of patients	2DE technique and findings	3DE-MPR technique
1	TR	5	TR severity estimation by conventional 2DE, Doppler derived methods; however; they have their own limitations	VCA precisely determined by MPR for TR severity gradation, overcomes the limitations of 2DE without geometric assumptions for the shape of the TV and VC. (Fig. 2A and B)
2	TVS	2	By peak and mean pressure gradients measurements across the TV and indirectly by assessing RA size	TVS revealed precisely by MPR planimetry of the TV without geometric assumptions to the TV's shape
3	TVP	1	Imaginary line is placed at the TV annulus hinge points and RA is then inspected for any possible prolapse	By physically placing an actual colour-coded line along the TV hinge points, parallel to the TV horizontal axis in the parasternal long axis view through the RV inflow tract, revealing even trivial degree of prolapse in the corresponding colour coded box without need for assumption or imagination
4	DORV	3	Relationship of the great vessels to the ventricles and to the VSD was unclear in 3 patients using conventional 2DE alone	Great vessels commitment to the underlying ventricles and the VSD were clearly delineated influencing the surgical decision so two underwent biventricular repair and the 3rd patient underwent univentricular palliation
5	TOF	1	Disconnected LPA clearly demonstrated by 2DE	No further findings could be gathered
6	MR	3	MR estimation using the VC width usually but assumes that the VC shape is either circular or elliptical	Planimetry of VCA precisely determined by MPR for MR severity gradation and also revealed varying shapes of VC
7	MVS	5	MVS severity determined by MVA and Doppler-based methods; however, they have their own limitations.	MVA estimation by the MPR is independent of hemodynamic variables and is actually estimated in ideal short axis plane
8	MVP	5	Imaginary line is placed at the MV annulus hinge points in the PSLAx view and LA is then inspected for any possible prolapse	Actual colour-coded bar was physically placed at the MV annulus hinge points in the PSLAx views of the three patients and LA was then inspected in the corresponding colour coded box for any possible prolapse without any assumption or imagination (Fig. 3A and B)
9	AR	3	AR severity estimation using VCW measurement by incorrectly assuming circular or elliptical shape of VCA	VCA measured precisely by 3DE MPR for AR severity gradation with no assumptions
10	AVS	4	2DE estimation of AVS included Doppler gradient across the AoV and AVA estimation by continuity equation approach (AVA = LVOT area (velocity time integral LVOT/velocity time integralvalve))	Precise measurement of AV area with planimetry but low cardiac output was potential limiting factor
11	ASD	5	Droup out and left to right shunt across the droup out in the intratrial septum using 2DE, preferably subcostal 4 chamber or bicaval views, confirm the diagnosis of ASD in most cases	MPR 3DE provided unique enface views for the exact shape of the ASD as seen from LA or RA perspectives, adequacy of the rims and relationship with the surroundings' anatomical structures
12	Complex CHD	6	Several windows, sweeps in addition to more time required by 2DE to achieve similar findings achieved by 3DE complex CHD segmental analysis using one window	One window of a four-chamber view full volume dataset was enough for complex segmental analysis of the entire intracardiac lesion by 3DE MPR, regardless the complexity of the lesion

TR = tricuspid valve regurgitation, 2DE = two dimensional echocardiography, RA = right atrium, RV = right ventricle, CW = continuous wave, RF = regurgitant fraction, EROA = effective regurgitant orifice area, VCA = vena contracta area, MPR = multiplanar reformatting, TV = tricuspid valve, VC = vena contracta, TVS = tricuspid valve stenosis, TVP = tricuspid valve prolapse, DORV = double outlet right ventricle, TOF = tetralogy of fallot, LPA = left pulmonary artery, MR = mitral valve regurgitation, MVS = mitral valve stenosis, MVA = MVA-mitral valve area, MVP = mitral valve prolapse, PSLAx = parasternal long axis, LA = left atrium, AR = aortic valve regurgitation, VCW = vena contracta width, AVS = aortic valve stenosis, AoV = aortic valve, AVA = aortic valve area, LVOT = left ventricular outflow tract obstruction, ASD = atrial septal defect, CHD = congenital heart disease.

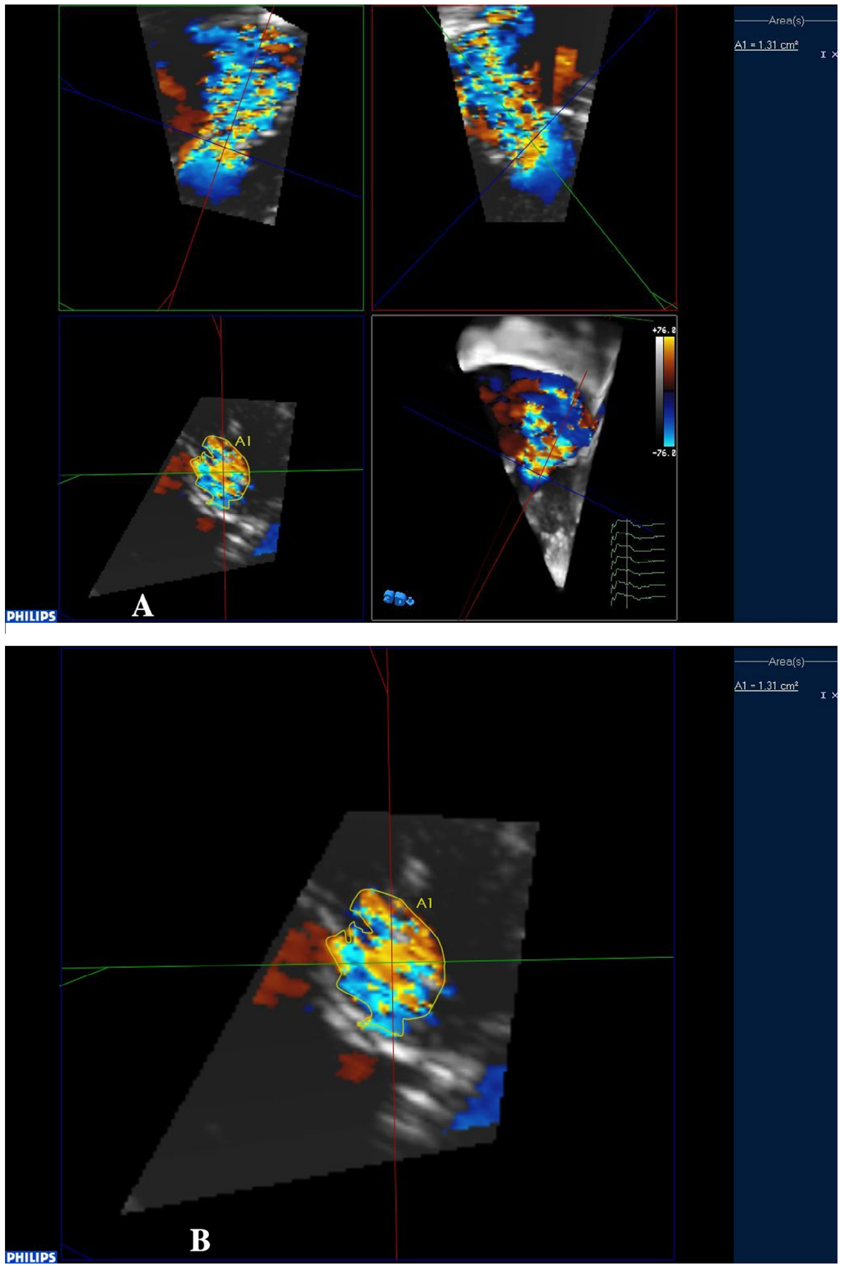

Figure 2. (A) Multiplanar reformatting (MPR) technique used to grade Tricuspid valve regurgitation (TR) severity demonstrating three colour-coded boxes with 4th box in the right lower quadrant showing full volume three-dimensional echocardiography (3DE) dataset. (B) Blue box in the left lower quadrant is enlarged to calculate the severity of TR by vena contracta planimetry, and it was graded to severe TR.

tricuspid valve (TV) pathology (e.g. TV prolapse) from RA and RV perspectives. This study looked into the second analytical method which is the MPR technique.

This study outlines the initial experience of the feasibility and reproducibility of 3DE dataset analysis by MPR technique in evaluating patients with valvular and CHD and its advantages over 2DE in daily routine practice at Medina Cardiac Centre in Al Medina Al Munawwarah, Saudi Arabia.

Methods

This prospective study enrolled 43 patients (23 males and 20 females) with various forms of valvular and structural heart disease diagnosed by 2DE, referred from various parts of Medina Province for further evaluation. Their age varied from 30 days to 146 months (mean age, 70.2 months and SD = 42.5 months) and their weight from 4 to 42 kg (mean weight, 20.2 kg and SD = 9.7 kg). The

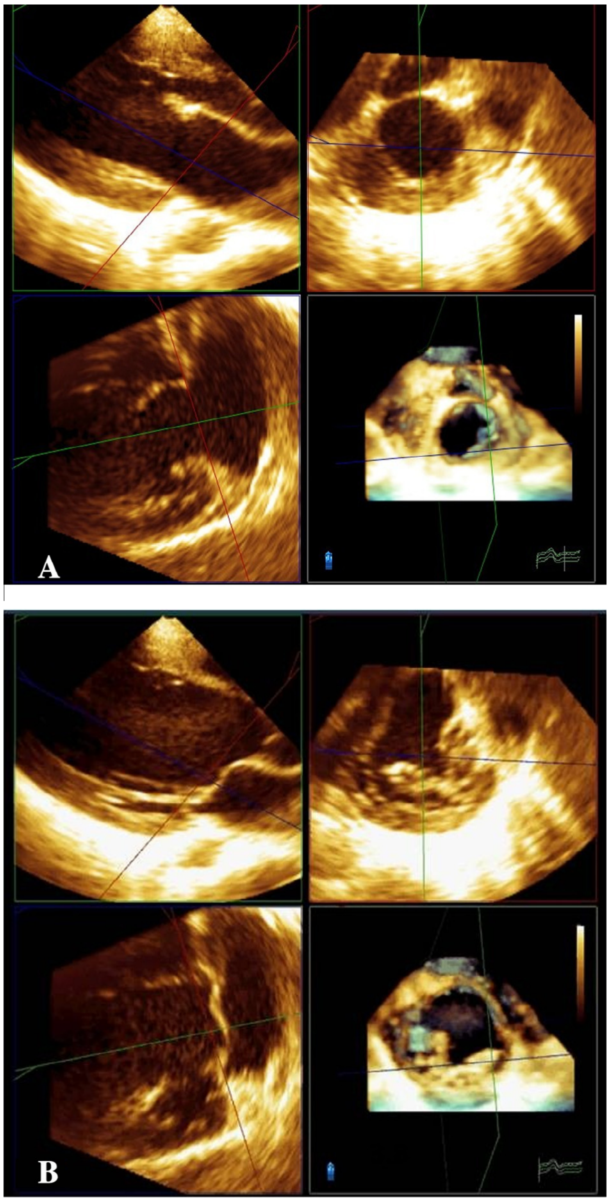

Figure 3. Multiplanar reformatting (MPR) technique used to detect even trivial Mitral valve prolapse (MVP) demonstrating three colour-coded boxes with 4th box in the right lower quadrant showing full volume three-dimensional echocardiography (3DE) dataset. (A) In diastolic phase putting actual physical line along the hinge points of the MV in the blue box (left lower guardant box) and in the green box (left upper quadrant box) demonstrating no MV tissue in the left atrium (LA) in the red box (right upper quadrant box). (B) during systole; with MV closure, MV tissue started to appear in the left atrium (LA) in the red box (right upper quadrant) confirming the MVP. Note that since the red colour-coded bar was placed in the blue and green boxes, the changes are traced in the corresponding colour-coded box, which is the red box here.

only exclusion criterion was significant arrhythmia, as this made obtaining full-volume 3DE datasets difficult. The study was approved by the Medina Cardiac Centre Research Ethics Committee. An X7-2 matrix array (transducer frequency, 2–7 MHz) was used to acquire a 3DE dataset for each patient. Various tasks, including TT (transthoracic) 2DE, Doppler and real-time transthoracic (RTT)-3DE, were performed with the same matrix array transducer. For overweight patients, full-volume RTT-3DE datasets were acquired with an X3-1 matrix array transducer (frequency, 1–3 MHz).

The four recognized methods for RTT-3DE data acquisition are Live 3DE, Zoomed mode, 3D colour Doppler mode and full-volume acquisition mode; [6] the latter was mainly used in the current study. The various forms of valvular and structural heart diseases were diagnosed first by conventional TT-2DE and then by full-volume RTT-3DE to obtain 90° × 90° pyramidal volumes, which accommodate large cardiac structures, over four to seven cardiac cycles with an additional 10 min for overall scanning (average scanning time, 20–25 min per patient). The acquired RTT-3DE datasets were stored on the machine's hard disk in the DICOM format. The datasets were analysed off-line with QLAB Advanced Quantification software (Philips Ultrasound, USA) installed in the IE-33 echography machine (Philips, Bothell, Washington, USA). The MPR button is activated, and the echograph displays three colour-coded imaging planes that move spontaneously (Fig. 1). Any cardiac structure of interest to the operator (e.g. atrioventricular valves, intratrial or interventricular septa) can be evaluated individually by moving the colour-coded bar, and the structure of interest can be evaluated in the corresponding colour-coded box [7]. Cropped images stored on the hard disk of the machines in the audio–video interleaved and bitmap formats were then transferred to a CD-ROM for presentation to cardiac surgeons and cardiologists, who drew up the final management plan.

Results

The imaging quality was sufficient to allow MPR analysis for all 43 patients enrolled in the study. The results of RTT 3DE dataset analysis with the MPR technique were reviewed and compared with those obtained by 2DE. The average time required for 2DE and 3DE data acquisition, including patient preparation, was 20–25 min, and the time for analysis of the 3DE data was 15 ± 5 min. The primary diagnoses based on 2DE examination and the new findings provided by the 3DE data set analysis using MPR technique in the study group are shown in Table 1.

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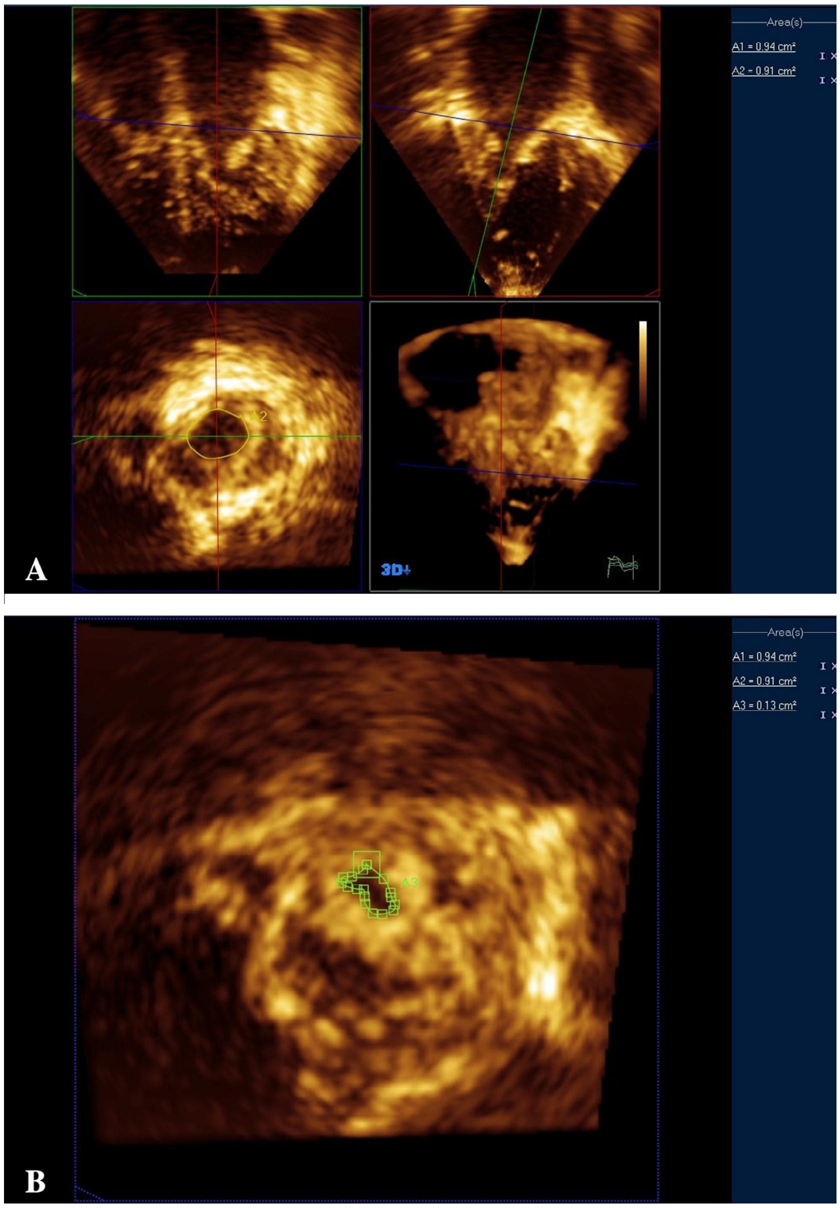

Figure 4. (A) Multiplanar reformatting (MPR) technique used to grade Mitral valve stenosis (MVS) severity demonstrating three colour-coded boxes with 4th box in the right lower quadrant showing full volume three-dimensional echocardiography (3DE) dataset. (B) Blue box in the left lower quadrant is enlarged to calculate the severity of MVS by planimeteric determination of mitral valve area (MVA) and it was graded as severe MVS.

In patients with valvular regurgitation, the 3DE MPR technique made it possible to determine mechanism and severity, which altered our decisions for appropriate management. Two of three patients with mitral valve regurgitation (MR) were sent for surgical repair. The 3DE MPR technique showed the severity of MR in the third patient to be mild, and the managing team decided on conservative treatment. In two of three patients with aortic valve regurgitation (AR), the condition was found to be severe by 3DE MPR, and they were sent for Ross surgical repair. The third patient was found to have mild disease and was treated conservatively. In two of five patients with tricuspid valve (TV) regurgitation (TR), the conditions were confirmed by 3DE MPR technique as severe (Fig. 2A and B), and TR mechanism was clearly revealed to be due to previous surgical closure of a perimembranous ventricular septal defect (VSD), in which the septal leaflet of the TV was involved in the surgical patch. These two patients were rescheduled for surgical repair of the TV. In two further patients with TR, the mechanism was identified by 3DE MPR technique to be a fistulous connection between the left ventricle (LV) and the right atrium (RA) through the TV (Gerbode defect), which was successfully closed by appropriate devices. In the fifth patient, the severity of TR was found by 3DE MPR technique to be mild, and conservative treatment was chosen. In one patient with TV prolapse (TVP), 3DE MPR technique confirmed that the prolapse was minimal and the severity of TR was mild, with subsequent conservative management. In three of five patients with mitral valve prolapse (MVP), the condition was found by 3DE MPR to be minimal (Fig. 3A and B) and the severity of MR to be mild, and for whom conservative treatment was considered. In the remaining two patients, the degree of prolapse and the severity of MR were found to be moderately severe, and these patients were scheduled for MV surgical repair. In one patient with the Tetralogy of Fallot (TOF) and a disconnected left pulmonary artery (LPA), 3DE MPR technique confidently identified the disconnected artery; however, the finding was also clearly shown by conventional 2DE. In two patients with TV stenosis, the stenosis was revealed precisely by MPR planimetry of the TV without geometric assumptions to the shape of the TV.

In five mitral valve stenosis patients (Fig. 4A and B) and four aortic valve stenosis patients, 3DE MPR technique played a major role in helping the treatment team to decide whether to send the patient for surgical, percutaneous or conservative management. 3DE MPR technique was also useful for deciding the management of three patients with a double outlet right ventricle (DORV). In the first patient who had a subaortic VSD, MPR showed the VSD was tunable to the aorta. In the second patient who had malposed great arteries, MPR showed the VSD was tunable to the pulmonary artery (followed by switch operation). In the third patient who had a non-committed VSD, MPR showed a remote VSD, in which biventricular repair was not possible.

In five patients with atrial septal defect (ASD), the 3DE MPR technique clearly localized the site, size and unique enface views for the exact shape of the ASD as seen from LA or RA perspectives. They underwent successful device closure. RTT-3DE strongly influenced the choice of technique and the type of the device selected for ASD device closure. Finally, in six patients with complex CHD, one window of a four-chamber view full volume dataset was enough for complex segmental analysis of the entire intracardiac lesion by 3DE MPR, despite the complexity of the lesion, compared to several windows and sweeps and more time required to achieve similar findings by 2DE complex CHD segmental analysis.

Discussion

This study demonstrates the superiority of RTT-3DE with the MPR technique over 2D-TTE in delineating anatomical structures. Seliem et al., [8] Takahashi et al. [9] and our study show that RTT-3DE with MPR technique is not a substitute for 2D-TTE, but rather complements it.

RTT-3DE-MPR has several advantages, including the production of full 3DE images with a depth and thickness similar to those obtained by direct cropping, and also a full-volume dataset that can illustrate any cardiac structure of interest in three orthogonal planes, similar to 2DE planes. A full 3DE image of the fourth plane is also shown, making RTT-3DE-MPR a transition between conventional 2DE and 3DE. It is a known fact that in order to have excellent 3DE images, crystal clear 2DE images are required. However, compared to the direct cropping analysis method of the 3DE data set in the current study we found MPR analysis can reproduce relatively good enface images, better than those achieved by direct cropping analysis of the 3DE dataset when the image quality obtained is relatively poor. The same findings were demonstrated by Bharucha et al. [7] This study supports other studies [10–15] in demonstrating the feasibility and the superior value of RTT-3DE MPR over 2D-TTE as the former delineates the detailed anatomy of CHD, septal defects and both sided cardiac lesions, thus rendering it more reliable. Several previous reports have described the additional potential of RTT-3DE in valvular heart lesions evaluation in the adult population [16–18]. Our report adds to the few studies [19,20] that have demonstrated the added value of RTT-3DE in the valvular lesion evaluation of infants' and children's hearts.

TR severity by conventional 2DE and Doppler can be calculated in multiple ways: by RA and RV end diastolic and systolic volumes, hepatic vein flow reversal, the presence of V notch on the continuous wave Doppler (CW) tracing of the TR jet, the measurement of the regurgitant volume and regurgitant fraction, and the effective regurgitant orifice area. However, calculations of these parameters are severely affected by concomitant regurgitation by the nearby valve as pulmonary valve regurgitation in most pediatric patients with TR is associated with accurate determination of RV volume by 2DE [21]. Measuring TR vena contracta (VC) by colour Doppler 2DE is the most up-to-date 2DE estimation method of TR severity but the variability of VC shapes is a major limitation for TR severity estimation using this method [22]. The RTT-3DE-MPR technique overcomes most of the above mentioned limitations and avoids any geometric assumptions for the shape of the TV and VC. It thus accurately determined the severity of TR in our patients (Fig. 2A and B) by quantitative estimation of the vena contracta area. Velayudhan et al. [22] reported similar findings, but further validation studies are required to establish the role of TR severity estimation by 3DE MPR technique.

In this study, two patients had TV stenosis, where MPR planimetry revealed the TV shape without geometric assumptions as contrary to 2DE. But as TV stenosis is a relatively rare occurrence in a paediatric population compared to MV stenosis, [21] not much work has been done on the evaluation of TV stenosis severity in this age group. There is therefore a need for more detailed research to establish the superiority and accuracy of the 3DE MPR technique over 2DE in TV stenosis estimation.

The current experience of 2DE diagnosis of MVP is performed by applying an imaginary line in the MV hinge points at the horizontal axis of the MV in the parasternal long axis view, and observing for MVP into LA in systole. This can be difficult and overcalling MVP, especially minor or mild prolapse that might be missed or over diagnosed particularly if we put in our mind the saddle shape of the normal MV. Our study adds to the current literature on MVP by trying to demonstrate the advantage of 3DE MPR technique over 2DE for MVP diagnosis using 3-color coded bars and observing changes in the corresponding 3-color coded boxes. By physically placing an actual colour-coded bar along the MV hinge points, parallel to the MV horizontal axis in the parasternal long axis (PSLAX) window (Fig. 3A and B), any degree of MVP, even trivial, can be detected in the corresponding colour box. (e.g. appearance of prolapsed tissue in left atrium during systole and LA which looks devoid of any tissue during diastole) without any imaginations or assumptions.

The 2DE Quantitation of MR using the VC width assumes that the VC shape is either circular or elliptical because the exact shape and area of the VC is not seen with 2D imaging. Khanna et al. [23] demonstrate the feasibility of obtaining the VC exact shape by 3DE MPR which estimates the severity of MR without assumptions for the VC shape. However, further evidence-based research is needed to validate its use in daily practice.

For MV stenosis, planimetry of MV orifice, pressure half time, continuity equation and proximal iso-velocity surface area (PISA) are acceptable methods for assessment of the mitral valve area (MVA) through conventional 2DE. However, this has its own limitations [24]. Doppler-based methods are of limited value as they are heavily dependent on coexisting valvular lesions and hemodynamic variables [25,26]. As with Zamorano et al., [27] we found that estimation of the mitral valve area (MVA) by RTT 3DE (Fig. 4A and B) overcomes most 2DE limitations, is independent of hemodynamic variables, and is more accurate than 2DE-TTE as it measures actual anatomical valve area in an ideal short axis plane. Theoretically, these facts also hold true for aortic, tricuspid and pulmonary valve stenosis estimation by RTT 3DE [24].

For aortic valve (AoV) stenosis, the severity of AS is currently estimated by 2DE, Doppler-derived measurements of effective AVA. However, the Doppler method has some limitations when used in patients with LV outflow tract obstruction (LVOT), in bicuspid aortic valves with an eccentric jet, in the presence of concomitant significant aortic regurgitation, or when the left ventricular function is impaired [28–31]. Goland et al. [32] affirm the complementary role of 3DE-MPR in estimating the severity of AoV stenosis by measuring the AoV area which overcomes most of these limitations. However, low cardiac output may affect planimeteric measurement of AVA as the anatomic area of aortic valve opening is reduced, and will potentially result in an inaccurate measurement of AVA.

Vena contracta width (VCW) is the benchmark for AR severity estimation by 2DE and has good correlation with angiographic grading and regurgitant orifice area [33–36]. But by assuming circular or elliptical shape of VCA which is mostly incorrect assumption. While on the other hand this study and the study done by Fang et al. [37] found the superiority of 3DE MPR estimation of AR severity by vena contracta area measurement without assumptions.

In addition to the data achieved by 2DE, MPR 3DE has established its superiority by providing unique enface views for the exact shape of the ASD as seen from LA or RA perspectives, through the adequacy of the rims and through its relationship with the surrounding anatomical tissues. MPR 3DE was also able to more precisely determine the type and position of the ASD by slicing the colour coded bars and allowing observation of the changes in the corresponding colour coded box using the subcostal four chamber or subcostal short axis (bicaval) views. In our centre, we rarely carry out transesophageal echocardiography (TEE) or balloon sizing to assess size of the ASD or the adequacy of its rims. Our intervesionest mainly depends on transthoracic 2DE and 3DE direct cropping or MPR techniques which usually provide excellent enface views of the ASDs from both atrial sides. This is usually adequate for detecting device size and type selections. TEE is reserved for borderline challenge ASD cases, especially large ASD of around 30 mm or when the adequacy of the rims are questionable and require further delineation.

This study also demonstrated that transthoracic 3DE MPR supported post procedural evaluation (in cath lab on table immediately post ASD device deployment using mainly subcostal four chamber and bicaval views) in the assessment of device position in relation to surroundings with colour Doppler, and which confidently evaluated the possibility of any residual shunts.

This study was successful in establishing its superior role in various forms of CHD, but patients with Tetralogy of Fallot with disconnected left pulmonary artery were not much benefitted.

Lang et al. [38] highlighted the usefulness of 3DE in evaluating CHD but also pointed to its inability to incorporate into daily routine clinical practice because of cost-effectiveness, technical problems of resolution, image acquisition, processing and storage. Bhan et al. [6] noted that infrequent users of RTT-3DE continue to be unsure of its exact role, usefulness and drawbacks. The endless arguments on the merits and demerits of the routine clinical use of RTT-3DE are in the literature, but the evidence-based research reported here supports the usefulness of RTT-3DE alongside 2D-TTE in routine valvular and CHD evaluation.

Limitations of RTT-3DE

The inability to stay still and the difficulties acquiring full cooperation of breath holding in the pediatric population of this study are significant sources of stitch artifact during full volume. 3DE color flow Doppler mode acquisition over four to seven ECG-gated cardiac beats might affect the quality of the final 3DE enface view images. Stitch artifact also can be a major limitation in patients with significant arrhythmia, but the application of the newer software of single beat acquisition sounds promising. Spatial and temporal resolution were a limiting factor associated with 3DE techniques, especially when imaging patients with dilated ventricles or those who have high heart rates as in our pediatric population in the current study. Continuous improvement in computer technology software might overcome these limitations in the future.

Conclusion

RTT-3DE with MPR technique is a useful addition in the cardiologist's tool box for real-time valvular and CHD evaluation. This study confirms that RTT-3DE with MPR technique can provide additional information that significantly alters the clinical management of valvular and CHD patients. Further experience with the 3DE-MPR technique and advances in computer software technology will clearly improve diagnosis, the choice of intervention and the prognosis of these patients.

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